DEVELOPMENT OF WIRELESS TYPE K THERMOCOUPLE TEMPERATURE MEASUREMENT

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"I hereby acknowledge that the scope and quality of this thesis is qualified for the award of the Bachelor Degree of Electrical Engineering (Electronics)"

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ABSTRACT

This project will focus on how to develop a wireless type K Thermocouple temperature measurement. Visual Basic is used as a main programming language to develop a GUI (Graphical User Interface) application. Then, the sensor for this project is a Thermocouple type K. Wireless system is used to interface the GUI and the thermocouple sensor and ZigBee will be used for the wireless. Wireless temperature measurement system is developed using ZigBee communication technology. It overcomes the disadvantages of wired measurement system, such as complicated wiring and difficult maintenance. The wireless sensor networks based on ZigBee has the characteristics of insulation, strong electromagnetic immunity, low power and high accuracy, solving the problem of easy breaking, easy aging, cannot resist high temperature in traditional optical fiber temperature measurement technology, saving the trouble of wiring, ensuring the reliability and safety of the operation. For this project, the temperature measured by the thermocouple is transmitted to the PC by transceiver controlled by ZigBee, and the temperature data is managed by PC. The thermocouple sensor detected temperature change and send the input to software system where the input is converted from current into voltage signal. In GUI application, the data is recorded and manipulated to get the appropriate result.

ABSTRAK

Projek ini akan menumpukan pada bagaimana untuk membangunkan sistem pengukuran suhu tanpa wayar menggunakan termogandingan jenis K. Visual Basic digunakan sebagai sistem perisian utama untuk mencipta aplikasi GUI (Graphical User Interface). Kemudian, pengesan yang digunakan untuk projek ini adalah pengesan termogandingan jenis K. Sistem tanpa wayar digunakan untuk menyambungkan antara aplikasi GUI dan pengesan termogandingan dimana ZigBee digunakan sebagai teknologi tanpa wayar.Sistem pengukuran suhu tanpa wayar dibangunkan menggunakan teknologi komunikasi ZigBee. Ini mengatasi kelemahan sistem pengukuran kabel, seperti kabel rumit dan penyelenggaraan yang sukar. Rangkaian pengesan tanpa wayar berdasarkan ZigBee mempunyai ciri-ciri insulasi, kekebalan elektromagnet yang kuat, penggunaan kuasa yang rendah dan ketepatan yang tinggi, menyelesaikan masalah mudah pecah, mudah rosak, tidak boleh menahan suhu yang tinggi dalam teknologi serat suhu tradisional optik pengukuran, menyimpan data gangguan kabel, memastikan ketahanan dan keselamatan operasi. Untuk projek ini, suhu yang diukur dengan termogandingan dihantar ke PC dengan alat yang dikendalikan oleh ZigBee, dan data suhu yang dikendalikan oleh PC. Pengesan termogandingan mengesan perubahan suhu dan menghantar input ke sistem perisian di mana input tersebut ditukar dari arus menjadi isyarat voltan. Dalam aplikasi GUI, data akan dicatat dan dimanipulasi untuk mendapatkan hasil yang sesuai.

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LIST OF ABBREVIATIONS

IEEE	Institute of Electrical and Electronics Engineers
RFD	Reduced Function Device
FFD	Full Function Device
GUI	Graphical User Interface
IDE	Integrated Development Environment
WPAN	Wireless Personal Area Networks
DSSS	Direct sequence spread spectrum
BPSK	Binary phase shift keying
REMF	Relative Error Membership Function
OSI	Open System Interconnection
ISO	International Organization for Standardization
ZDO	ZigBee Device Object
ZDP	ZigBee Device Profile
SSP	Security Service Provider
API	Application Programming Interface

CHAPTER 1

INTRODUCTION

1.1 Introduction to temperature measurement using ZigBee

Temperature is a common variation, and temperature monitoring is also an important and basic part of industry field. The traditional temperature monitor system often needs a master node connected with monitor computer and some slave nodes distributed in the environment. And master and slave nodes are connected by such as RS485/RS232 cable to form a monitoring network, data or signal are transmitted between them. However, some factors in complex industrial environment may cause corrosion of cable, such as oil stain. This situation may affect the quality of communications, even lead to the failure. Besides, the rate of change in the temperature monitor system is not fast, which leads to the data transmitting rate is slow, and data quantity is not large, therefore, the temperature monitoring system could adopt wireless transmission technology. ZigBee is an open specification that enables low power consumption, low cost and low data rate (250kb/s) for short-range wireless connections between various electronic devices, which is a proper scheme applicated in temperature monitoring system.

The ZigBee standard is built on top of the IEEE 802.15.4 standard, which defines the physical and MAC layer for low rate wireless personal area networks. It

also supports functionalities for channel selection, link quality estimation, energy measurement and clear channel assessment. ZigBee also defines the NWK layer, the application layer and the security layer which are used to form network and ensure security of wireless data transmission.

Two types of devices RFD (Reduced Function Device) and FFD (Full Function Device) could be recognized by ZigBee architecture, and can build three kinds of network topology structure, star topology, tree topology and mesh topology Each ZigBee network only has a coordinator, which acts as the administrator and takes care of organization of the network. Only the FFD defines the full ZigBee functionality and can become a network coordinator. The RFD has limited resources and does not allow some advanced functions. All main characters of ZigBee are analyzed above is suitable for forming an industrial wireless temperature monitoring system.

1.2 Objectives of the project

There are three main objectives of the project which are:

i. To develop GUI (Graphical User Interface) application using Visual Basic.

   Visual Basic will be use as a main programming language.

ii. To interface the GUI application and the temperature transmitter output.

   The interface process can be done using the Zigbee. ZigBee will be used to interface between instrument and computer.

iii. To monitor the temperature measurement directly by software application.

   Temperature measurement is the way that can be used to measure temperature where data from measurement process can be directly used for other purpose.

1.3 Problem statement

In the industrial, temperature measurement is one of the most frequently measured parameters in process system. Temperature detectors have become industry standards for simple and cost-effective temperature measurement. However, achieving such measurement in an accurate, reliable and cost-effective manner is a challenging problem. If station is far away from the workplace, it is difficult to collect and monitor temperature changes. It wastes time to take and check temperature reading at plant station. They also need to analysis and monitor the data everyday or weekly to make sure the instrument in good condition.

1.4 Scope of project

This project involves designing the software application to analysis the data using Microsoft Visual Basic 2008 Express Edition. Visual Basic 2008 used to develop GUI (Graphical User Interface) application. The interfacing process between GUI application and the temperature transmitter instrument can be done using Zigbee wireless technology. Thermocouple type K is used as a primary transducer to detect temperature changes in Isotech Jupiter temperature bath. Besides Isotech Jupiter and thermocouple, temperature transmitter, hart communicator and digital manometer also will be use as a temperature transmitter instrument for this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Thermocouple

Thermocouples are widely used in industry and in testing and research laboratories for measuring temperature. Thermocouple techniques have been developed to meet the specific requirements of many applications. One of those applications is the measurement of metallic surface temperatures [1]. Two thermocouple wires are attached to the metallic surface, and that metallic surface completes the thermoelectric circuit. Possible advantages of physically separating the junction include the following:

- The effects of the thermocouple wires on the temperature being measured are minimized. For example, conduction of heat away from a point on the surface is less from the attachment of a single wire than from a pair.
- If a standard thermocouple junction is attached to the surface and the thermocouple wires are twisted above the junction, this can sometimes cause an inadvertent short between the wires. The temperature measurement is then made at the location of that short and not on the surface as intended. The separated junction method may reduce the likelihood of such an error [2].

In 1826, Thomas Seebeck discovered that a circuit composed of two dissimilar metals will generate an EMF if the junctions at the ends of those metals are kept at different temperatures. Figure 2.1 shows a thermocouple circuit consisting of two metals A and B, with junctions at temperatures T (test junction) and Tr (reference junction).

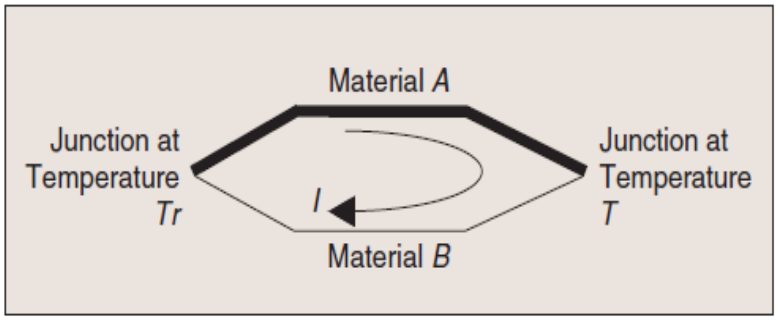

Figure 2.1: Thermocouple circuit of materials A and B [2]

If the reference junction temperature remains constant, the Seebeck EMF (εAB) is a function of the test junction temperature. As the temperature difference between the two junctions increases, εAB increases and a current *(I)* flows through the circuit. If the junction at Tr is opened and connected to a thermocouple meter, as shown in Figure 2.2 the measured voltage will be a function of temperature *T* as defined by εAB. This Seebeck voltage is nonlinear with respect to the temperature difference $T - Tr$ [3].

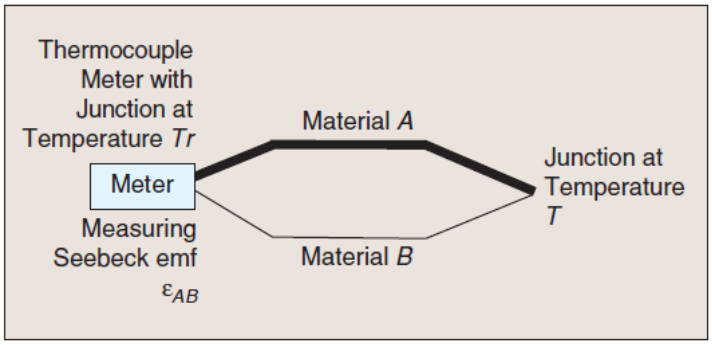

Figure 2.2: Thermocouple circuit with junction of Tr opened [3]

The Seebeck coefficient for materials *A* and *B,* also known as the thermoelectric power, is defined in equation (2.1):

$$SAB = \lim_{\Delta T \to 0} \frac{\Delta \in AB}{\Delta T} = \frac{d \in AB}{dT} \quad (2.1)$$

where *T* is temperature, and εAB is the Seebeck EMF [3,4].

2.2 Thermocouple type

Thermocouples are available in different combinations of metals or calibrations. The four most common calibrations are J, K, T and E. Each calibration has a different temperature range and environment, although the maximum temperature varies with the diameter of the wire used in the thermocouple.

Some of the thermocouple types have standardized with calibration tables, colour codes and assigned letter-designations. The ASTM Standard E230 provides all the specifications for most of the common industrial grades, including letter designation, colour codes, suggested use limits and the complete voltage versus temperature tables for cold junctions maintained at 32 ^{o}F and 0 ^{o}C [5].

There are four classes of thermocouples:

- The home body class (called base metal)
- the upper crust class (called rare metal or precious metal)
- the rarified class (refractory metals)
- The exotic class (standards and developmental devices)

Table 2.1 shows the thermocouple type. The home bodies are the Types E, J, K, N and T. The upper crusts are types B, S, and R, platinum all to vary percentages.

Table 2.1: Thermocouple type [5]

J	Iron – constantan	-190 ^{o}C to 760 ^{o}C
T	Copper - constantan	-200 ^{o}C to 371 ^{o}C
K	Chromel – alumel	-190 ^{o}C to 1260 ^{o}C
E	Chromel - constantan	100 ^{o}C to 1260 ^{o}C
S	90% platinum + 10% rhodium – platinum	0 ^{o}C to 1482 ^{o}C
R	87% platinum + 13% rhodium – platinum	0 ^{o}C to 1482 ^{o}C

2.3 Visual Basic

Microsoft Visual Basic is designed for graphical user interface (GUI) programming. It is not a general purpose programming language. For example, you would not want to write a compiler in Visual Basic. It is not a procedural language. Microsoft calls Visual Basic an event-driven programming language. Since the sequence of events that a user chooses is practically unlimited, the programmer must code each event independently in such a way that it can interact with other events. Event-driven programming is ideally suited for object oriented programming techniques.

Visual Studio provides an environment that's common to all languages, which as known as an integrated development environment (IDE).The purpose of the IDE is to enable developer to do as possible with visual tools, before writing code . The IDE provides tools for designing, executing and debugging [6]

Visual Basic objects have properties, methods, and events. Properties define the identity and state of an object. Methods and events define the behaviour of an object [7].

Microsoft defines properties, methods, and events as follows:

1. Property: A named attribute of an object. Properties define object characteristics, such as size, colour, screen location, or whether the object is enabled. Every Visual Basic object has a property called name.

2. Event: An action recognized by an object, such as clicking the mouse or pressing a key. You can write code to respond to events. Events can occur as a result of a user or program action, or they can be triggered by the system.
3. Method: A Subroutine or Function that operates on an object [7].

2.4 PIC Microcontroller

The PIC microcontroller family is manufactured by Microchip Technology Inc. Currently; they are one of the most popular microcontrollers, used in many commercial and industrial applications. Over 120 millions devices are sold each year.

The PIC microcontroller architecture is based on a modified Harvard RISC (Reduced Instruction Set Computer) instruction set with dual – bus architecture, providing fast and flexible design with an easy migration path from only 6 pins to 80 pins and from 384 bytes to 128 Kbytes of program memory [8].

PIC microcontrollers are available with many different specifications depending on:

- Memory Type
  - Flash, OTP(one–time–programmable), ROM, ROMless
- Input – Output pin count
- Memory Size
- Special Features
  - LCD, Motor Control, Radio Frequency, CAN, USB.

Although there are many models of PIC microcontrollers, the nice thing is that they are upward compatible with each other and a program developed for one model very easily, in many cases with no modifications, be run on other models of the family .The basic assembler instruction set of PIC microcontrollers consists of only 33 instructions and most of the family members (except the newly developed devices) use the same instruction set [8].

All PIC microcontrollers offer the following features;

- RISC instruction set with only a handful of instructions to learn
- Digital I/O ports
- On – chip timer with 8 – bit prescalar
- Power – on reset
- Watchdog timer
- Power – saving SLEEP mode
- High source and sink current
- Direct, indirect, and relative addressing modes
- External clock interface
- RAM data memory
- EPROM or Flash program memory

2.4.1 PICAXE 18X

The PICAXE 18X is a PIC16F88 microcontroller loaded with a Basic Stamp style P-Code interpreter. The chip's functionality and development environment are very similar to a Basic Stamp 2's. The quality of documentation is good. The chip is programmed using a minimal version of BASIC or a unique flowcharting system.

It only has 16 bytes of variable space. However, it has another 256 bytes of "data memory" for temporary storage. The chip has enough program space for approximately 600 BASIC commands. It does not have a built-in voltage regulator - but it can operate anywhere from 2v to 5.5v

The PICAXE-18X offers:

- 600 lines memory
- 8 inputs
- 8 outputs
- I2C Interfacing for easy peripheral connecting
- 8/10-bit Analog-to-Digital converters (ADC)
- 8MHz maximum operation speed (4MHz normally)

- Supports
    - Interrupts
    - 12-Bit Digital tempertaure sensors
    - Servo control
    - Keyboard input
    - IR transmit/receive
    - Plays user-defined musical tones
    - PWM Motor control
    - Input Pulse counting
    - Serial output & debugging via programming cable
    - Higher baud rate for serial work
- Based on the PIC 16F88 IC

The ‘PICAXE’ system is a powerful, low cost microcontroller programming system designed to simplify educational and hobbyist use of microcontrollers. PICAXE chips can be programmed in a graphical 'flow-chart' environment or in easy to understand BASIC. Figure 2.3 shows the PICAXE -18X pins configuration.

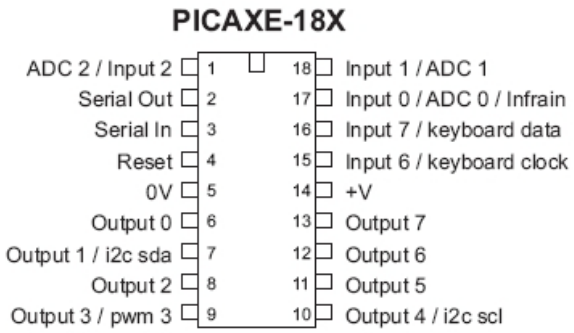

Figure 2.3: PICAXE-18x pins

2.5 Wireless Measurement System based on ZigBee Transmission Technology.

The ZigBee (IEEE 802.15.4) is a new technology that permits the implementation of Wireless Personal Area Networks (WPAN). It is very suitable for wireless sensor networks due to the very low power consumption. This was one of the reasons why it was choose for the implementation of the system presented in this paper [10]. Summarizing, the main advantages of ZigBee in comparison with other technologies such Bluetooth or WiFi are the following:

- flexible network architecture
- low cost
- low power consumption
- large number of nodes (≤ 65.536)
- compatibility of equipments from divers producers

The main disadvantages are:

- low transmission speed
- the existence of an single point of failure represented by ZigBee coordinator

The ZigBee technology allows the operation in so called mesh networks that are low cost, self organizing networks of ZigBee devices. The components of the mesh networks can operate over extended periods of time, even years, without changing the original battery. The ZigBee devices operate in unlicensed radio frequency bands (ISM). These unlicensed bands are not the same in all regions of the world, those the ZigBee devices can operate in three frequency bands centered on 868, 915 and 2400MHz. The most advantageous frequency band is at 2400MHz because of higher data rate (250kb/s) and the worldwide availability. In the 2402–2480 MHz frequency band is used offset quadrature phase-shift keying (O-QPSK) modulation technique. In the 868 and 902-928 frequency bands are used DSSS (Direct sequence spread spectrum) and BPSK (Binary phase shift keying) [11].

In the structure of ZigBee networks the devices can be of tree types: Zigbee Coordinator, Zigbee Router and the Zigbee End Device.